

EXPERIMENTAL INVESTIGATION OF PEAT HYDROGASIFICATION

F. D. Raniere, L. P. Combs, and A. Y. Falk

Energy Systems Group
Rockwell International
8900 De Soto Avenue
Canoga Park, California 91304

INTRODUCTION

The availability and accessibility of peat as a domestic fossil resource have been well publicized by Minnesota Gas (Minnegasco) and the Institute of Gas Technology (IGT) (References 1 and 2). It has been established that peat, with an estimated 1440 quads (10^{15} Btu) of available energy, is second only to coal as the most abundant fossil energy resource in the United States. Also, hydrogasification tests at IGT (Reference 1) have shown that, due to peat's unique properties of high volatility and hydrogen-to-carbon ratio, peat is highly reactive yielding good conversion to methane.

Based on these studies and the concurrent DOE-sponsored* development of a short residence time coal hydrogasifier at Rockwell International, with the Cities Service Research and Development Company as a subcontractor, an additional task to the existing DOE contract was established to furnish a preliminary performance profile for peat in the Rockwell hydrogasifier. Rockwell and Cities Service have entered into an agreement to develop jointly short-residence-time, flash hydro-pyrolysis process technology. Acknowledgement is given to both Louis Jablansky and Melvyn Kopstein of DOE for their administration of this add-on effort.

The background technology and details of development for the Rockwell hydrogasifier reactor have been previously reported over the last few years (References 3, 4, and 5). However, a brief review is necessary to establish the conditions under which the peat hydrogasification tests were made.

The Rockwell reactor is based on the application of rocket engine techniques to achieve rapid mixing-reaction at optimum temperature and residence time. Adjustment of reactor conditions, principally temperature and residence time, allows a range of product distribution from predominantly liquids to complete gasification to substitute natural gas (SNG). Intermediate conditions permit maximized yields of byproduct BTX (benzene, toluene, and xylene).

Successful operation has been demonstrated at engineering scales from 1/4- to 1-ton/h (tph) feedrates. This success was achieved by feeding dry, pulverized carbonaceous solids (coal or peat) into the reactor with a minimum of carrier gas (dense-phase flow) and there, achieving almost instantaneous mixing and concurrent heating with a preheated gaseous hydrogen stream. Reactor conditions were controlled to produce the desired products (liquids or gas). The current reactor development program (DOE Contract ET-78-C-01-3125) will optimize the injector-reactor configuration at 4 tph and be a full-scale element for straightforward, multi-element scaling to commercial-size reactors.

REACTOR SYSTEM

A description of the dense-phase, dry-solids feed system has been presented in previous papers and reports (References 3 and 4). Without modification, this

*Hydrogasifier Development for the Hydrane Process, Contract EX-77-C-01-2518, Louis Jablansky, Department of Energy (DOE) Program Manager.

system was used to feed dry, ground reed sedge Minnesota peat (<10% moisture and 78% through 200 mesh) with no problems at the 1/4-tph test level. Sieve analyses for a typical sample of peat and the resulting char are shown in Figure 1.

The reactor system (see Figure 2), as also described in References 3 and 4, uses a stream of hot hydrogen as the working fluid for the reaction. Hydrogen is preheated to 1100°F in an electrical heater, then to 2000 to 2100°F by combusting a small amount of hydrogen with oxygen in a preburner assembly. After rapid, injector-induced mixing (and heating) of the dry solids (coal or peat) with the hot hydrogen, the resulting reaction products are cooled at the appropriate residence time to achieve the desired product distribution. Cooling is accomplished with a water spray, which reduces the product gas temperature to 600 to 1000°F. The vapor phase products are separated from the char, and subsequently directed through a high-pressure, water-cooled condenser to remove water and any oils which may have been produced. The vapors are then sampled and regulated down to the appropriate venting pressure (<100 psig). Before venting, an activated-carbon, packed-bed adsorber is used to recover the vapor-phase BTX from the product stream.

Char is collected in a spherical receiver (located just under the water spray quench as shown in Figure 2) until completion of the test. Vapor-phase condensate is decanted (if necessary) to separate oil product for analysis. The char, gas, oil, condensed aqueous phase, and the activated carbon are analyzed to permit material balance calculations. It is important to mention that no modifications of the reactor system (as used for coal hydrogasification) are necessary to conduct the peat test.

PEAT TEST RESULTS

Ultimate and proximate analyses for the dried and ground peat, as received, are presented in Table 1. Eleven hydrogasification tests were conducted as shown in Table 2 at the 1/4-tph test level. Due to limited feed tank volume, test durations were ~6 to 10 min. The data are quite consistent, with high overall carbon conversions up to 84.2%, with the principal products being methane (CH₄) and carbon monoxide (CO). Small amounts (1 to 2%) of carbon dioxide were obtained. Except for the very low temperature Run 54, all of the liquids produced were essentially pure benzene.

TABLE 1
CHARACTERISTICS OF PEAT TESTED

	Minnesota Peat	
	As Received	Dry
Proximate Analysis (%)		
Moisture	9.40	—
Ash	16.87	18.62
Volatiles	53.76	59.34
Fixed Carbon	19.97	22.04
Ultimate Analysis (%)		
Moisture	9.40	—
Carbon	42.44	46.84
Hydrogen	4.50	4.97
Nitrogen	1.60	1.77
Chlorine	0.03	0.03
Sulfur	0.18	0.20
Ash	16.87	18.62
Oxygen (by diff.)	24.98	27.57
Heating Value (Btu/lb)	7,596	8,328

Figure 3 shows the effect of reactor residence time on overall carbon conversion and specific conversion to liquids (the difference is the conversion to gas). Liquid byproduct can be eliminated by high temperature (>1800°F) and longer residence time (>2.8 s). Data points are segregated into two reactor exhaust temperature groups. This graph shows that conversion is a function of residence time and temperature predominantly and essentially independent of pressure within the range of 500 to 1500 psig. The mild effect of reactor temperature is shown in Figure 4. The total carbon conversion increases slightly as reactor temperature is increased from 1550 to 1850°F. The apparent effect of pressure in Figure 4 is caused by the concurrent increase in residence time as pressure is increased in a given reactor configuration. Two different size reactor tubes were used to isolate the effect of pressure

from residence time. The low overall conversion and low conversion to gases of Run 54, which had a reactor temperature of only $\sim 1000^{\circ}\text{F}$, are dramatically shown in Figure 4.

Conversion to benzene as a function of reactor temperature is magnified in Figure 5. Conversion ranged from 0.0 to 11.7 wt % benzene as an inverse function of temperature and residence time. This graph (Figure 5) is useful for defining reactor conditions required for elimination of liquid product. One hundred percent selectivity to gases with an overall carbon conversion of 84% is attainable in a 3-s residence reactor at reactor temperatures above $\sim 1850^{\circ}\text{F}$. As shown in Table 2, analyses of the product gas composition for peat indicate that, in general, the carbon is converted primarily to CH_4 and CO at a mole ratio of $\sim 2:1$ (CH_4 to CO). Almost all of the carbon monoxide results from the relatively high oxygen content of the peat.

DISCUSSION

Using a computerized analytical model of the fluid dynamics and specific hydrogenation reactions, previously developed for coal conversion (Reference 6), peat results show consistent agreement with coal data (see Figure 6). The model assumes steady-state, one-dimensional (plug) flow, which is typical of the uniform flow patterns of rocket-type injectors at short distances from the injector face.

In order to compare these peat results for the Rockwell hydrogasifier with other peat hydrogenation investigations, the test data were plotted on a published IGT graph of hydrocarbon gas yield vs reactor temperature (Reference 1) for similar peat hydrogasification tests. Figure 7 shows this comparison. The Rockwell data are seen to be consistent with extrapolation of the IGT data to high reactor temperatures, and therefore to higher conversion levels. Together with the relative ease of processing peat in the unmodified Rockwell coal hydrogasifier, these high conversion levels provide encouraging support to the concept of peat hydrogasification to produce SNG. A commercial peat SNG plant might differ from one based on coal mainly in the more stringent requirements for drying the peat and for methanating the greater quantity of carbon monoxide.

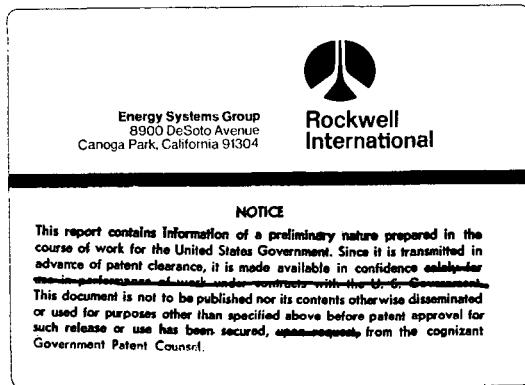
CONCLUSIONS

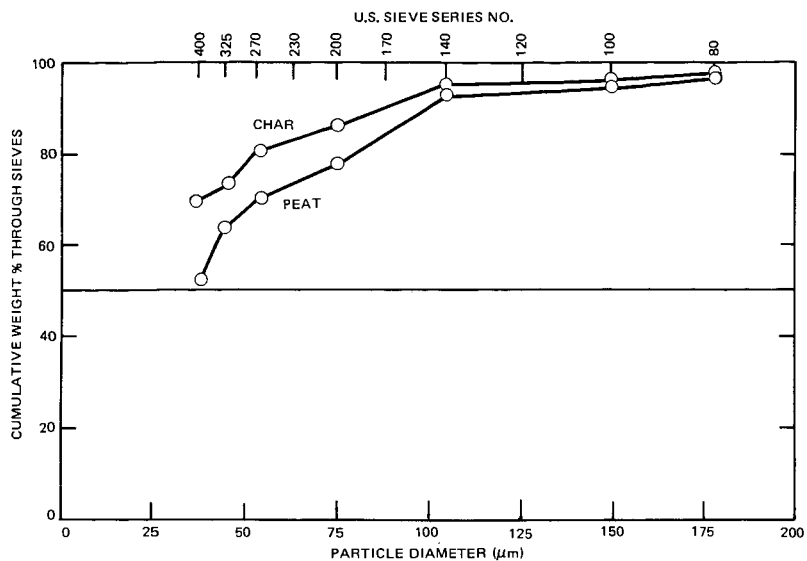
The results of this experimental investigation clearly demonstrate that the Rockwell Flash Hydrogasifier is one of the most effective reactors for converting peat to SNG. Overall carbon conversions up to 84% with benzene byproduct yield ranging from 0 to nearly 12% were achieved. Both overall carbon conversion and conversion to benzene were found to be functions of reactor temperature and residence time, but not to depend upon reactor operating pressure. Rapid hydrogasification should be considered as a prime candidate for converting our abundant peat reserves to SNG.

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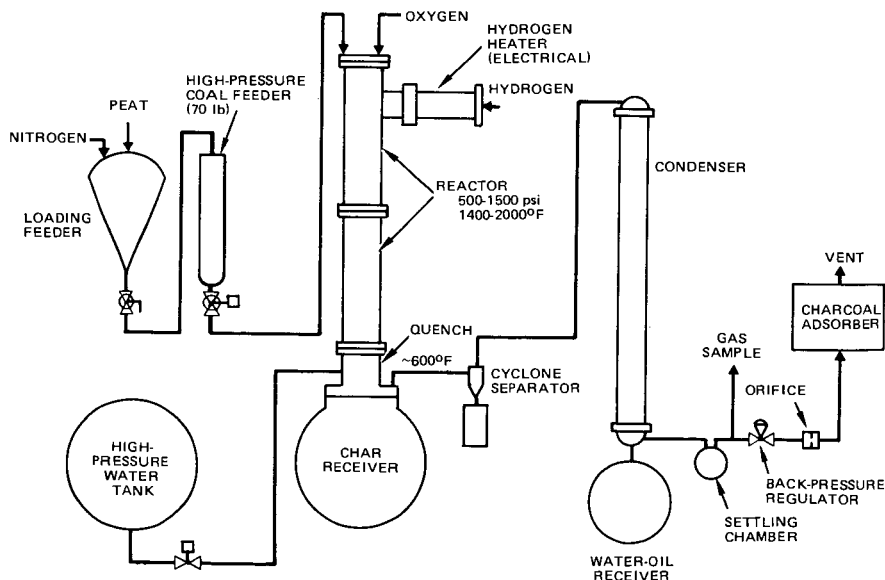
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- 6) K. M. Sprouse, "Theory of Pulverized Coal Conversion In Entrained Flows, Part I: Hydrogasification," Rockwell International Technical Memorandum, NTIS FE-2518-14, December 1977





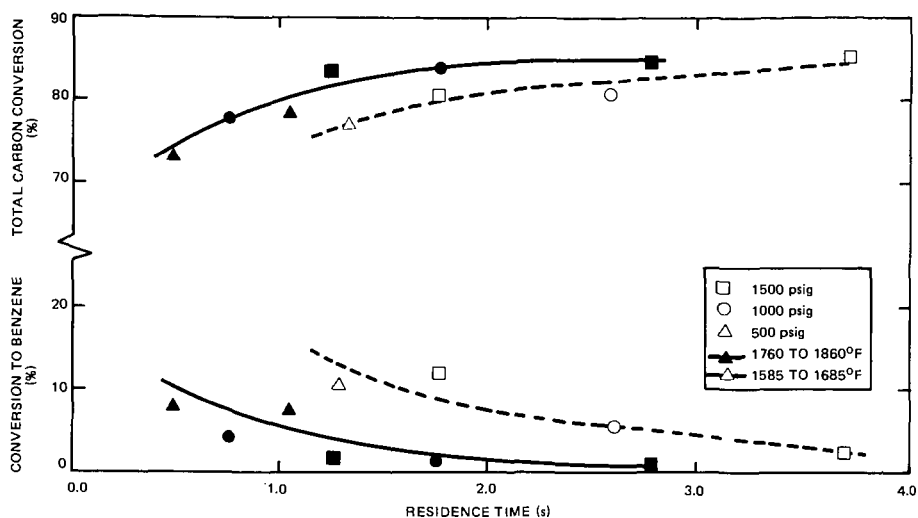
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Figure 1. Peat and Char Sieve Analyses



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Figure 2. Simplified Flow Diagram of Rockwell 1/4-TPH Hydrogasifier System



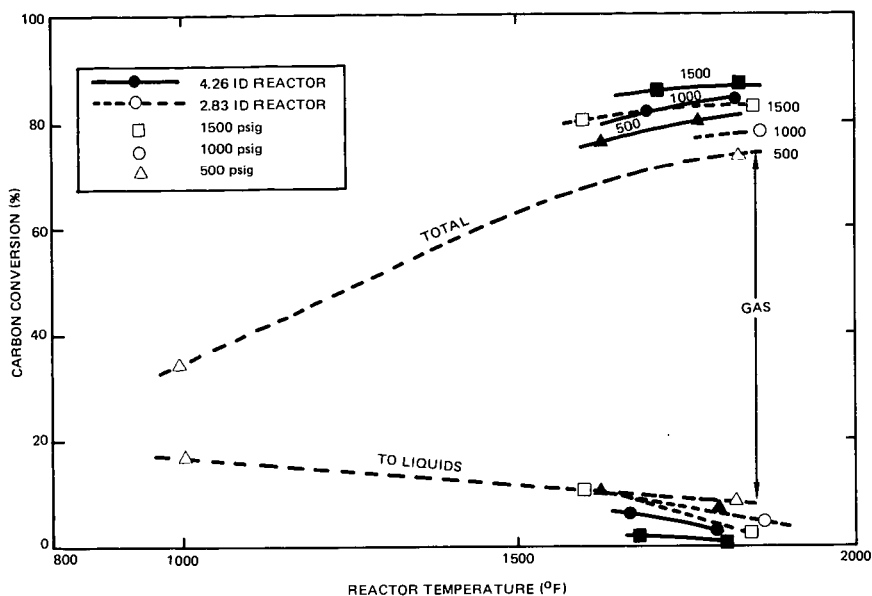
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Figure 3. Carbon Conversion as a Function of Reactor Residence Time

TABLE 2
TEST RESULTS

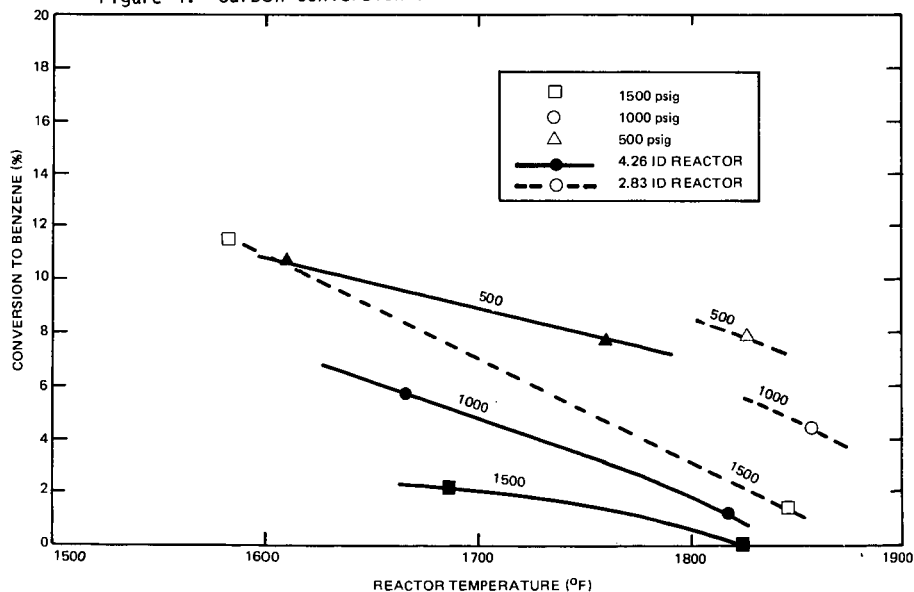
Run No.	Reactor Conditions					Carbon Conversion (%)				Heating Value (H ₂ -Free Basis) (Btu/scf)
	Diameter (in.)	P (psig)	T (°F)	T _R (s)	H ₂ /Peat	Total	CH ₄	CO	Benzene*	
44	4.26	1500	1685	3.7	0.66	84.9	58.7	23.3	2.1	808
45	4.26	1000	1667	2.6	0.61	80.8	49.9	24.0	5.8	778
46	4.26	1000	1815	1.8	0.93	83.3	52.7	28.3	1.2	761
47	4.26	500	1610	1.3	0.53	76.6	39.8	24.8	10.5	731
48	4.26	500	1760	1.1	0.84	79.0	42.7	27.1	7.9	732
49	4.26	1500	1825	2.8	0.90	84.2	59.3	24.0	0.0	788
50	2.83	1500	1847	1.2	0.85	83.8	56.4	25.0	1.5	792
51	2.83	1500	1584	1.7	0.60	80.1	43.0	24.4	11.7	752
52	2.83	535	1825	0.5	0.57	73.4	38.9	25.3	7.9	726
53	2.83	1000	1857	0.8	0.91	77.4	46.7	25.3	4.4	760
54	2.83	500	998	0.8	0.59	34.2	1.6	7.2	16.2	330

*Liquids are vapor phase benzene for all tests except No. 54



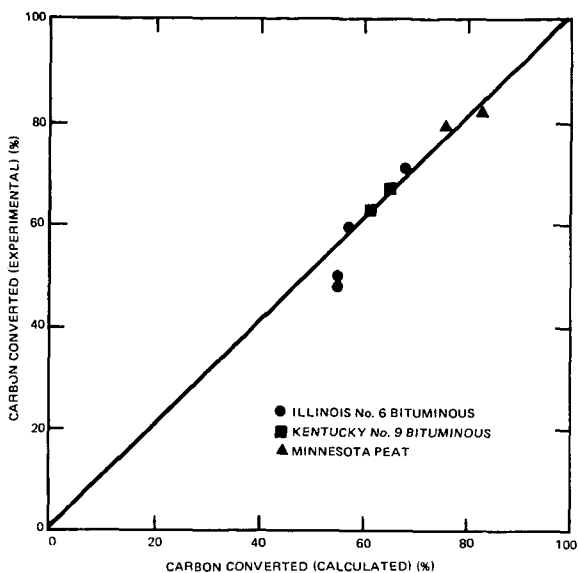
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Figure 4. Carbon Conversion as a Function of Reactor Temperature



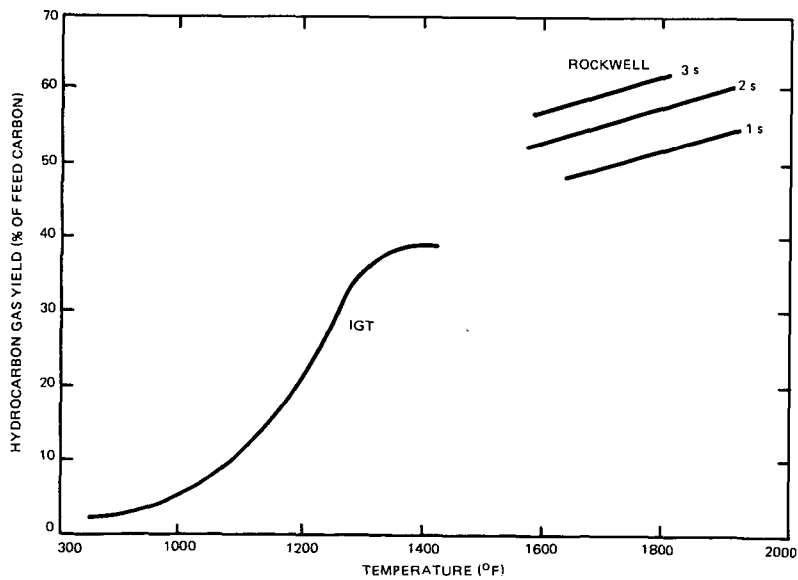
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Figure 5. Carbon Conversion to Benzene as a Function of Reactor Temperature



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Figure 6. Comparison of Reactor Model With Experimental Data



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Figure 7. Comparison of Hydrocarbon Gas Yields for Peat